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Emergence of Red Rice (*Oryza sativa*) Ecotypes Under Dry-Seeded Rice (*Oryza sativa*) Culture[1]

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Abstract: The effect of seeding depth on emergence of red rice (*Oryza sativa*) ecotypes from Arkansas (AR), Louisiana (LA), and Mississippi (MS) was determined under dry-seeded rice production in clay and silt loam soils in Arkansas. By 21 d after planting (DAP), all red rice ecotypes had emerged from planting depths of 1.3, 2.5, 5.0, and 7.5 cm in both clay and silt loam soils. In silt loam soil, seedling emergence from 2.5 cm 7 DAP tended to be greater than from 1.3 cm in an early (normal temperature) planting. Also in this situation, the LA ecotype emerged more vigorously than the other ecotypes at all seeding depths and emerged from 7.5 cm at levels 1.5 times those of the other ecotypes at the same depth. In the clay soil, seedling emergence from 7.5 cm at 21 DAP was greater for the LA and MS ecotypes than for the AR ecotype in an early planting, but these differences were not observed for a late (elevated temperature) planting. Seedling emergence was earlier and greater in silt loam than in clay. The LA ecotype generally produced the greatest aboveground dry matter, especially at the early planting. The MS ecotype averaged 30% less dry matter production than the AR ecotype for the late planting in both soils. The ability of the LA and MS ecotypes to emerge from greater depths than the AR ecotype under certain soil and temperature conditions suggests that they could be more difficult to control with cultural practices used in dry-seeded rice culture.

Nomenclature: Red rice, *Oryza sativa* L. #[3] ORYSA; rice, *Oryza sativa* L. ‘Alan’.

Additional index words: Germination, red rice emergence depth, soil texture.

Abbreviations: AGDM, aboveground dry matter; AR, Arkansas ecotype; DAP, days after planting; LA, Louisiana ecotype; MS, Mississippi ecotype.

INTRODUCTION

Red rice (*Oryza sativa*) has been recognized as a weed in U.S. rice fields for 150 yr. In 1846, Allston (as noted by Constantin 1960) reported red rice plants with either golden or white hulls resembling earlier cultivated rices. It has been estimated that red rice causes losses of $50 million annually (Smith 1979) in the U.S. and $10 million in Arkansas alone (Baldwin et al. 1989). Present losses due to red rice are probably higher than these estimates because rice hectarage and overall severity of red rice infestations in Arkansas have increased since estimates were made (F. L. Baldwin, personal communication). Rice specialists recently have estimated that severe, economic infestations of red rice occur on approximately 65% of the rice area in Louisiana; 25% in Arkansas, Texas, and Missouri; and 15% in Mississippi. It was further estimated that 100% of the rice produced in Louisiana and approximately 75% of that produced in Arkansas is infested with red rice to some degree (F. L. Baldwin, J. M. Chandler, A. Kendig, A. Klosterboer, M. Kurtz, S. Linscombe, and E. Webster, personal communication). Red rice is such a severe problem in southern Louisiana that approximately 80% of the rice grown in the state is water-seeded (rice sown into standing water) in order to reduce the losses due to red rice. In the remaining rice-producing areas of the southern United States, most farmers use dry-seeded (rice drilled into moist soil) production systems which are more prone to red rice infestations.

Rice yields are reduced by the severe competition from red rice, and the prices received per ton of rough rice are reduced if the rice is contaminated with red rice kernels. Discounts due to red rice contamination cost Arkansas farmers alone $3.24 million in the 4-yr period from 1985 to 1987, and 1989 (Helms et al. 1990). Milling costs of rice contaminated with red rice are higher

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[3] Letters following this symbol are a WSSA-approved computer code from *Composite List of Weeds,* Revised 1989. Available only on computer disk from WSSA, 810 East 10th Street, Lawrence, KS 66044-8897.

because the duration of the milling process must be extended to destroy the pericarp of red rice, which also results in a greater fraction of broken white rice kernels and lower head rice yields (Smith 1981).

Red rice is an annual plant that reproduces by seeds (Smith and Shaw 1966). It has a red pericarp of varying color intensity, and sometimes the red is present throughout the endosperm (Dodson 1898). The plant has a spreading habit and tillers profusely, and tillers are bent 65 degrees with respect to the vertical (Dodson 1898; Quereau 1920). In the field, the leaf color of red rice is a particular yellowish-green that contrasts clearly with the darker green of the domestic rice (William 1956). The leaves are longer, wider, and rougher than those of domestic rice (Diarra et al. 1985; Do Lago 1982; Smith 1981). The panicle is lax and open with fewer grains than the commercial varieties (Dodson 1898). The two general types of red rice are strawhull and blackhull, with strawhull being the more common (Diarra et al. 1985).

Based on micromorphological studies, red rice is considered the same species as domestic rice (Hoagland and Paul 1978). Red rice can cross naturally with domestic rice, and the rate of hybridization will depend on the degree of overlapping of the flowering period between red rice and the domestic rice varieties (Langevin et al. 1990). Red rice seeds develop a primary dormancy when attached to the rachis and shatter extensively after physiological maturity. These characteristics are very important to the persistence of red rice seeds in infested fields (Dodson 1898).

Seedling emergence from various soil depths has been studied in several weed species. Dawson and Bruns (1962) reported seedlings of barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.], green foxtail [*Setaria viridis* (L.) Beauv.], and yellow foxtail [*Setaria glauca* (L.) Beauv.] emerged when seeds were buried at a 12.5-cm depth in a Sagemoor fine sandy loam. Seedling emergence of downy brome (*Bromus tectorum* L.) was greater from depths of 2.5 cm or less under field conditions (Wicks et al. 1971). Emergence was greater and occurred from deeper depths in silt loam than in sandy loam or silty clay loam soil. Hull (1964) reported that more cheatgrass (*Bromus tectorum* L.) emerged from the soil surface to 5 cm than fairway [*Agropyron cristatum* (L.) Gaertn.], crested [*A. desertorum* (Fisch.) Schult.], or siberian [*A. sibiricum* (Willd.) Beauv.] wheatgrasses. Under controlled conditions, Wiese and Davis (1967) determined that greatest emergence occurred from a 1.3-cm depth of planting followed by 0.6, 2.5, 5, and 10 cm for seedlings of tumblegrass [*Schedonnardus paniculatus* (Nutt.) Trel.], redroot pigweed (*Amaranthus retroflexus* L.), and barnyardgrass. They also obtained an optimal emergence for all species at 18/27 C night/day temperatures. In Texas, Helpert (1978) reported that emergence of nondormant strawhull and blackhull red rice was greater than the domestic rice cultivars evaluated. Red rice seedlings emerged from 16 cm in a sandy soil, but not from 16 cm in a clay. According to Takahashi (1984), differences in mesocotyl growth between most indica and japonica cultivars determine their ability to emerge from greater soil depths.

Information is lacking on emergence of red rice ecotypes in the field under domestic rice production systems. A better understanding of emergence of red rice ecotypes may help in formulating weed management strategies. The objective of this study was to assess the emergence of red rice ecotypes relative to four seeding depths in Sharkey clay and in Crowley silt loam soils under dry-seeded production conditions.

MATERIALS AND METHODS

Field experiments were conducted in summer 1995 at the University of Arkansas Southeast Branch and Extension Center at Rohwer, AR, and at the Rice Research and Extension Center at Stuttgart, AR, using red rice ecotypes originating from Louisiana (LA), Mississippi (MS), and Arkansas (AR) and the commercial cultivar Alan as a reference standard. The red rice seed originating from LA previously was designated LA 3 and described as a goldhull, long-awned type with dormant seeds whose plants matured in 115 d (Noldin et al. 1999). The MS ecotype previously was designated MS 4 by Noldin et al. (1999) and R-78-8 by Do Lago (1982). It was described as a brownhull, short-awned type with deeply dormant seeds that reached maturity at 115 d (Do Lago 1982). Seeds of both the LA and MS ecotypes were obtained from field plots at College Station, TX, in 1993 and were air dried and stored at or below 10 C (J. A. Noldin and J. M. Chandler, personal communication) until field experiments were established in Arkansas in 1995. The AR ecotype previously was designated SHR-AR by Diarra et al. (1985) and StgS by Gealy et al. (1999) and was described as a strawhull, generally awnless type that reached maturity in 120 d (Diarra et al. 1985). Seeds of the AR ecotype were obtained from plants grown at Stuttgart, AR, and were dried and stored in conditions similar to those described in Texas.

Before establishing field experiments, seeds of the red rice ecotypes were tested for germination and vigor at

25 C in the dark (Anonymous 1983). Germination of AR, LA, and MS ecotypes was 93, 100, and 95%, respectively. Shoot plus root dry weight per viable seed of AR, LA, and MS ecotypes was 3.8, 4.6, and 4.6 mg, respectively. Dry grain weights per 1,000 seeds of AR, LA, and MS ecotypes were 27.5, 25.0, and 21.8 g, respectively. Germination and dry grain weight per 1,000 seeds of the Alan standard were 100% and 21.9 g, respectively.

To simulate normal and above-normal temperatures at time of planting, pots containing red rice or rice seeds were placed in the field on May 19 (early planting) and June 23 (late planting) at Rohwer and June 1 (early planting) and July 26 (late planting) at Stuttgart. The period from approximately April 15 to June 1 is considered to be the ''normal'' planting time for this region. Therefore, only the ''early'' plantings in these experiments fall within normal planting practices for the region. ''Late'' plantings in these experiments are not representative of normal agronomic practices of the region and were included primarily as a means of achieving above-normal planting temperatures. The soil type at Rohwer was a Sharkey clay (very fine montmorillonitic, nonacid, thermic, Vertic Haplaquept) and at Stuttgart was a Crowley silt loam (fine, montmorillonitic, thermic Typic Albaqualf).

Plastic pots (19 cm top diam by 15 cm bottom diam by 13 cm deep) with holes in the bottoms were filled with either air-dried Sharkey clay in Rohwer or Crowley silt loam in Stuttgart and subirrigated. After wetting, the volume of each soil changed. Sharkey clay expanded upon wetting; therefore, some of this soil was removed from each pot. The Crowley silt loam shrank upon wetting; therefore, each pot was supplemented with additional silt loam soil to offset the shrinkage. Ten seeds of each ecotype were seeded into pots, with a separate pot for each planting depth and ecotype, and the seeds were covered with air-dried soil. The air-dried soil was gently compacted to simulate the seedbed density present in drill-seeded rice fields. The pots were buried to a depth in the field plots such that the edges of the pots were even with the soil surface and the soil inside the pots was at the same level as soil in the surrounding field. This arrangement allowed flood irrigation water to reach the soil surface in the pots. The pots served as barriers that effectively prevented intermingling of the planted red rice ecotypes with the red rice already in the field soil. Pots for the two planting dates were planted in separate, adjacent bays (approximately 8 by 30 m), and planting dates were considered to be separate experiments.

A four by three factorial arrangement of treatments (four seeding depths and three ecotypes) plus the Alan cultivar check in a randomized complete block design with three replications was used for each planting date experiment. Seeding depths were 1.3, 2.5, 5, and 7.5 cm. The commercial cultivar Alan was planted only at 2.5 cm as a reference species to determine the appropriate timing of fertilization and water management practices based on Arkansas recommendations and was not included in any analysis. Experiments were conducted under dry-seeded soil conditions similar to those used in farmers' fields in the region.

At both locations, experiments were fertilized with urea at 228 kg N/ha applied in a three-way split. At the four- or five-leaf stage of Alan, 50% of the total amount was applied just prior to flooding the bay with 5 cm of water. Two weeks after flooding, 25% of the total nitrogen was applied. The remaining 25% of the nitrogen was applied 2 wk after the second application. At Stuttgart, 68 kg K/ha as potassium chloride and 46 kg P/ha as calcium superphosphate were thoroughly incorporated in the soil prior to seeding.

Seedling emergence was recorded approximately every other day for 3 wk following planting. Only data from 4, 7, and 21 d after planting (DAP) are presented in this report. A seedling was considered emerged when the coleoptile broke through the soil surface (Helms and Slaton 1994). Data were expressed as percent emergence based on 10 seeds planted in each pot. The aboveground portions of red rice plants were harvested when the cumulative heat units after planting totaled approximately 1,114 $\pm$ 62 heat units, which was usually 60 to 70 DAP. The daily heat unit accumulation was calculated using simple growing degree equations for rice, with 10 C as the base temperature. Daily heat unit accumulation = {[(daily maximum temperature in degrees C + daily minimum temperature in degrees C)/2] − 10 C}, as adjusted by the modification of Slaton et al. (1994). After harvest, plants were dried in an oven at 60 C for 4 d, and the weight of the aboveground dry matter (AGDM) was determined.

Emergence data were transformed by the arcsine of the square root of the percent emergence divided by 100. Because results of the ANOVA and means separation procedures were similar for transformed and nontransformed data, the nontransformed data on emergence were used directly. Because of lack of homogeneity of variance between locations, a separate analysis (ecotype by planting depth factorial) was conducted for each planting date experiment and location. A protected LSD test at the 5% level of probability was used to separate means.

Table 1. Emergence of red rice ecotypes and Alan rice cultivar 4, 7, and 21 d after planting (DAP) in a Sharkey clay in Rohwer, AR, and a Crowley silt loam (SL) in Stuttgart, AR, under dry-seeded culture as influence by early and late planting dates.[a]

		Early planting date (DAP)						Late planting date (DAP)					
		4		7		21		4		7		21	
Red rice ecotype[b]	Seed depth	Clay	SL	Clay	SL	Clay	SL	Clay	SL	Clay	SL	Clay	SL
	cm	%											
AR	1.3	0	17	70	53	90	80	17	43	99	70	99	73
	2.5	0	7	62	83	91	87	0	47	83	83	89	83
	5.0	0	0	29	60	92	77	0	17	33	87	73	90
	7.5	0	3	0	47	50	67	0	0	0	67	30	77
LA	1.3	0	13	80	77	90	93	20	87	90	90	97	93
	2.5	0	20	77	97	87	100	0	67	83	90	89	90
	5.0	0	13	20	87	93	87	0	43	47	93	93	97
	7.5	0	0	13	77	93	87	0	0	30	90	33	90
MS	1.3	0	3	77	37	97	90	3	80	67	90	90	90
	2.5	0	63	72	87	86	87	3	73	83	100	100	100
	5.0	0	7	33	80	81	83	0	20	17	97	90	97
	7.5	0	0	0	40	87	53	0	10	0	80	7	83
Alan rice[c]	2.5	0	67	40	80	73	80	0	60	30	91	87	91
LSD (0.05)		NS	24	37	28	23	19	14	23	35	15	36	14

[a] Early planting date was May 19, 1995, at Rohwer (clay) and June 1 at Stuttgart (silt loam). Late planting date was June 23 at Rohwer and July 26 at Stuttgart.

[b] Abbreviations: AR, Arkansas ecotype; LA, Lousiana ecotype; MS, Mississippi ecotype.

[c] Alan white rice cultivar was planted only at 2.5 cm as a reference and was omitted from the statistical analysis.

RESULTS AND DISCUSSION

Red Rice Emergence 4 DAP. In the clay soil at Rohwer, no red rice or rice seedlings emerged 4 DAP in the early planting (Table 1). In the late planting, the AR and LA ecotypes averaged 18% emergence from 1.3 cm but did not emerge from greater depths. Emergence of the MS ecotype at the late planting was 3% from 1.3- and 2.5-cm depths. The relatively greater emergence from shallow vs. deeper soil is an indication that surface soil moisture was not a constraint. In the early planting, the average air temperature during the first 4 DAP was 26 and 13 C for the daily maximum and minimum, respectively. By contrast, in the late planting, the average daily maximum and minimum air temperatures in the same period reached 33 and 19 C, respectively. The higher temperature also may have promoted emergence slightly at the late planting date, as would be expected under warmer conditions.

In the silt loam at Stuttgart, all ecotypes in both planting dates 4 DAP usually had emerged from soil depths less than 7.5 cm (Table 1). In the early planting, emergence of the MS ecotype from the 2.5-cm seeding depth was 63%, at least nine times greater than emergence from the other depths. This compares with 67% for Alan. None of the other ecotypes exhibited this rapid and pronounced maximum emergence from the 2.5-cm depth when seeded early. The reason for the differences among ecotypes is unclear, but probably relates to the ability of the MS ecotype to germinate and elongate more rapidly from the particular soil moisture and aeration conditions present at 2.5 cm of depth. Because these soil environment parameters were not measured in the present studies, controlled-environment physiological studies would be necessary to confirm any such effects and to elucidate the mechanisms responsible.

In the late planting in the silt loam, red rice emergence 4 DAP generally decreased with increasing soil depth, although the difference between 1.3 and 2.5 cm was not statistically significant (Table 1). Emergence of LA and MS ecotypes was greater than that of AR at the 1.3-cm depth, and emergence of the MS ecotype was greater than AR at 2.5 cm.

Within each soil, especially in the silt loam, red rice emergence was greater for the late than for the early planting date. In the late planting for the silt loam, the daily maximum and minimum temperatures averaged 33 and 22 C, respectively, for the 4-d period after planting. These temperatures were accompanied by high soil moisture levels from rainfall the day of planting. However, in the early planting, maximum and minimum temperatures averaged only 29 and 20 C, respectively, for the 4-d period after planting, and surface soil moisture content was less than that observed in the late planting. Higher temperature and increased soil moisture availability could explain the greater red rice emergence recorded from 1.3 cm for the late compared to the early planting. However, in the early planting, emergence of the MS ecotype from the silt loam was greater from 2.5 cm than 1.3 cm. According to Wiese and Davis (1967) and Dawson and Bruns (1962), when the soil dries rapidly, soil moisture surrounding the seed zone might become a constraint, or soil could crust at the surface. In the first case, emergence would be greater from a deeper soil depth than from shallow depths, and in the second case, emergence would be impeded or reduced from deeper planting. According to Takahashi (1984), an increase in temperature promotes coleoptile and mesocotyl growth in rice. The same response was observed in the mesocotyl of red rice (Diarra 1984), but information was not found on coleoptile growth in red rice. It is likely that the higher temperatures following the late planting compared to the early planting promoted an enhanced mesocotyl growth and subsequent increase in field emergence after the late planting.

Red Rice Emergence 7 DAP. Emergence 7 DAP was not different among red rice ecotypes in the clay soil for the 1.3- and 2.5-cm seeding depth at either planting date (Table 1). Emergence from 5 cm was low (17 to 47%) for all ecotypes. At the 7.5-cm depth, the LA ecotype began to emerge by 7 DAP in the clay soil, but there was no emergence of the AR and MS ecotypes at either the early or late planting date.

In the early planting in the silt loam soil 7 DAP, emergence of all ecotypes was numerically greatest (83 to 97%) from the 2.5-cm seeding depth (Table 1). Emergence of red rice ecotypes from 2.5 cm generally was greater (but only numerically greater for LA) than from 1.3 cm (similar to the response observed for the LA and MS ecotypes at 4 DAP). The LA ecotype emerged more vigorously than the other ecotypes, ranging from 77 to 97% emergence at all seeding depths (Table 1). Emergence of the LA ecotype from 7.5 cm was nearly 1.5 times that of the other ecotypes at the same depth. In contrast to the LA ecotype, emergence of the MS and AR ecotypes at the shallowest and deepest depth (1.3 and 7.5 cm) of the silt loam soil fell well below the maximum level at 2.5 cm. At these depths, emergence of the MS and AR ecotypes averaged only about half of that observed at the 2.5-cm depth. Emergence of all ecotypes from 2.5 cm was at least as great as that of Alan (80%).

In the late planting in the silt loam, emergence of the LA and MS ecotypes and Alan 7 DAP averaged 91% over seeding depths, which was greater than emergence of the AR ecotype at 77% ($P < 0.05$) (Table 1). Emergence of the AR ecotype tended to be poorer at the shallowest and deepest planting depths, similar to the early planting date.

Table 2. Aboveground dry matter of red rice ecotypes and Alan rice harvested 1,114 ± 62 heat units from planting in a Sharkey clay in Rohwer, AR, and a Crowley silt loam (SL) in Stuttgart, AR, under dry-seeded rice culture as influenced by early and late planting dates.[a]

Red rice ecotype[b]	Seed depth	Early planting date		Late planting date	
		Clay	SL	Clay	SL
	cm	g/pot			
AR	1.3	37.0	43.2	19.4	62.7
	2.5	30.8	47.0	24.6	53.4
	5.0	37.4	58.7	12.5	49.1
	7.5	27.4	41.8	5.8	47.0
LA	1.3	43.8	54.8	21.1	49.5
	2.5	42.2	60.2	20.2	52.1
	5.0	41.6	52.1	17.7	53.4
	7.5	37.4	46.0	11.5	38.5
MS	1.3	37.5	48.1	11.9	44.3
	2.5	32.5	44.8	15.5	43.7
	5.0	23.2	49.8	7.8	37.0
	7.5	26.9	35.5	3.3	27.9
Alan rice[c]	2.5	36.7	49.1	9.6	51.8
LSD (0.05)		11.8	13.6	11.2	9.7

[a] Early planting date was May 19, 1995, at Rohwer (clay) and June 1 at Stuttgart (silt loam). Late planting date was June 23 at Rohwer and July 26 at Stuttgart.

[b] Abbreviations: AR, Arkansas ecotype; LA, Louisiana ecotype; MS, Mississippi ecotype.

[c] Alan white rice cultivar was planted only at 2.5 cm as a reference and was ommitted from the statistical analysis.

Red Rice Emergence 21 DAP. By 21 DAP, emergence of most ecotypes at both planting dates and in both soils generally exceeded 80% (Table 1). Exceptions to this generalization were that emergence of the AR ecotype remained somewhat low at the 7.5-cm depth in both soils and planting dates, averaging about 40 and 70% in the clay and silt loam soils, respectively, and emergence of the MS ecotype from 7.5 cm was only 53% in the early planting in silt loam. However, emergence of LA and MS ecotypes from 7.5 cm at the early planting date in the clay soil was equal to that from the other depths. Emergence of all ecotypes from 7.5 cm was less than 35% in the late planting in the clay soil. Water leaked from neighboring bays into these plots through the clay-soil levees surrounding the plots. Furthermore, a rainfall of 80 mm occurred between 13 and 14 DAP. Oxygen depletion in the resulting saturated soil was probably a major reason for the reduced emergence from the 7.5-cm depth in Rohwer at this planting date.

Aboveground Dry Matter. Less AGDM was produced in clay at Rohwer than in silt loam at Stuttgart, especially at the late planting date (Table 2). Adequate water levels in the bays at Rohwer were difficult to maintain because the clay levees leaked water constantly. Once each day, the bays were replenished with water. Although the bays did not remain flooded, the clay soil remained water saturated most of the time. Averaged over seeding depths, the LA ecotype produced 17 and 27% more AGDM, respectively, than the AR and MS ecotypes for the early plantings in both soils, whereas LA and AR ecotypes had similar production for the late planting in the clay soil ($P < 0.05$; averaged data not shown).

The LA ecotype produced more tillers per pot than the AR or MS ecotype for both plantings in the clay soil and the early planting in the silt loam soil (data not shown), but no association was observed between number of tillers of LA and AR ecotypes and AGDM for the late planting in the clay soil. Although the numbers of tillers per pot were similar for AR and LA ecotypes, most of the tillers of the AR ecotype were heading (panicles exerted from the flag leaf sheath) at 1,114 $\pm$ 62 heat units (data not shown). However, LA and MS ecotypes still were in the vegetative phase.

The MS ecotype produced about 28% less AGDM than the AR ecotype for the late planting in the silt loam (Table 2). Averaged across both soils, the MS ecotype produced about 30% less AGDM than did the AR ecotype for the late planting ($P < 0.05$; averaged data not shown). Similarly, the MS ecotype produced fewer tillers than did the AR ecotype (data not shown).

Few significant differences occurred among AGDM values at the four planting depths (Table 2). Plants from the 7.5-cm depth tended to have less AGDM than those from the other depths, but the difference was significant, compared to the other depths, only with the LA and MS ecotypes at the late planting date. Normally there was overlapping significance or no significant differences among planting depths. When seedlings began emerging from deeper in the soil, especially from 7.5 cm, seedlings that had emerged from the 1.3- to 2.5-cm soil depths were already at the three-leaf stage. Seedlings from shallow depths started tillering earlier (data not shown).

In summary, all three red rice ecotypes eventually emerged to some degree from all planting depths tested (1.3 to 7.5 cm) in both the clay and silt loam soil. Emergence tended to be earlier and greater from the silt loam than from clay soil. Generally, the AR ecotype had the slowest, and lowest total emergence, whereas the LA ecotype produced the greatest AGDM (especially at early planting dates). Final red rice emergence from the 7.5-cm depth in soil was greater when the soil profile was well aerated and at high air temperatures than when the soil profile became water saturated. Therefore, greater populations of red rice seedlings emerging from buried seeds might be expected in years with warmer than average temperatures and/or lower than average rainfall or irrigation activities after planting. Currently, farmers who produce rice in dry-seeded production systems attempt to control red rice with herbicides primarily in the rotational crop, which is often soybean [*Glycine max* (L.) Merr.], that precedes rice or before planting in no-till situations. During the rice growing season, herbicides generally are ineffective against red rice. Therefore, cultural practices such as reducing the time period between domestic rice seeding date and establishment of a permanent flood may help reduce the potential number of red rice seedlings able to emerge and compete with rice. Red rice ecotypes that emerge aggressively from a range of soil depths and environments would have an advantage relative to other ecotypes that lack these characteristics. Our results suggest that LA and MS ecotypes probably would emerge from deeper in the soil than the AR ecotype in dry-seeded rice culture under well-aerated soil conditions after seeding or in the rotational summer crop. However, red rice seedlings emerging from deep in soil may escape herbicide activity and be capable of emerging later in the growing season, which may complicate the dynamics of emergence and survival of any particular red rice ecotype in dry-seeded rice culture.

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